# Highlights

## National Trends in R&D Expenditures

♦ **Total annual research and development (R&D) expenditures in the United States were $227 billion in 1998 by current estimates.** This level of R&D expenditure represents a 6.5 percent increase, after adjusting for inflation, over the $211 billion spent in 1997. In turn, the 1997 estimate represents a 5.5 percent increase over the 1996 level after adjusting for inflation.

♦ **The entire economy of the United States, as measured by gross domestic product (GDP), was estimated to reach $8,509 billion in 1998.** Adjusted for inflation, GDP increased by 3.9 percent per year in 1997 and 1998. Such growth in GDP is exceptionally high, yet it is slower than the growth of R&D. R&D has generally been outpacing the overall growth of the economy since 1994. As a result, R&D as a proportion of GDP has been on the rise as well—from 2.43 percent in 1994 to 2.67 percent in 1998.

♦ **Despite this recent increase, the R&D share of GDP (2.67 percent in 1998) is still below levels reached in the early 1990s** (e.g., 2.72 percent in 1991). Since 1957, the highest R&D/GDP ratio was 2.88 percent in 1964; the low was 2.13 percent in 1978.

♦ **Since 1980, industry has provided the largest share of financial support for R&D. Industry's share of funding for R&D was projected to reach $150 billion in 1998, or 66 percent of the total.**

♦ **Industrial R&D performance—predominately "development"—grew by only 0.7 percent per year in inflation-adjusted ("real") terms from 1985 to 1994.** From 1994 to 1998, that growth rate increased to 7.6 percent annually in real terms.

♦ **The most striking change in industrial R&D performance during the past two decades may be the nonmanufacturing sector's increased prominence.** Prior to 1983, nonmanufacturing industries accounted for less than 5 percent of the industry R&D total. By 1993, this percentage had risen to an all-time high of 26 percent. It has fallen only slightly since then and has remained above 22 percent.

♦ **Federal R&D support in 1998 reached $67 billion, as reported by performers doing the work.** The Federal Government once was the main provider of the Nation's R&D funds—accounting for as much as 67 percent in 1964. Its share of support first fell below 50 percent in 1979, and it remained between 45 and 47 percent from 1980 to 1988. Since 1988 it has fallen steadily to 29.5 percent in 1998—the lowest ever recorded in the National Science Foundation's (NSF) data series (which began in 1953).

♦ **The provision of Federal R&D obligations is concentrated from several agencies.** Six Federal agencies had R&D obligations of more than $1 billion in FY 1998, out of the total Federal R&D obligations of $72.1 billion. These six agencies are, in descending order of R&D obligations, the Department of Defense (DOD) (with a 48.3 percent share of the total), the Department of Health and Human Services (HHS) (19 percent), the National Aeronautics and Space Administration (NASA) (13.7 percent), the Department of Energy (DOE) (8.1 percent), NSF (3.3 percent), and the Department of Agriculture (USDA) (2.0 percent).

♦ **In contrast to total R&D obligations, only three agencies had intramural R&D expenditures that exceeded $1 billion in 1998, including costs associated with planning and administering extramural R&D programs:** DOD, HHS (which includes the National Institutes of Health), and NASA. These three agencies together accounted for 81 percent of all Federal R&D obligations for 1998 and 77 percent of Federal intramural R&D.

♦ **State governments also provide funding for R&D activities.** In 1995 (the most recent year for which these data are available), almost 25 percent of the $244 million state-funded, state-performed R&D was health related. Between 1965 and 1995, total state R&D spending increased at an inflation-adjusted average annual rate of 3.3 percent, compared with nationwide R&D spending growth of 2.5 percent per year over the same period.

♦ **Between 1953 and 1969, R&D expenditures grew at a real annual rate of 8.2 percent.** Starting in 1969 and for nearly a decade thereafter, however, R&D growth failed to keep up with either inflation or general increases in economic output. In fact, between 1969 and 1975, real R&D expenditures declined by 1 percent per year as business and government tended to deemphasize research programs. Between 1975 and 1985, R&D expenditures picked up again, averaging 5.6 percent real growth per year. That rate then slowed to 1.1 percent in 1985–94. In 1994–98, R&D expenditures rose sharply again, averaging 5.8 percent real growth per year. Almost all of the recent growth in national R&D expenditures is the result of a resurgence of industrial R&D.

♦ **R&D is substantially concentrated in a small number of states.** In 1997, California had the highest level of R&D expenditures—$41.7 billion, representing approximately one-fifth of the $199.1 billion U.S. total that could be attributed to individual states. The six states with the highest levels of R&D expenditures—California, Michigan, New York, New Jersey, Massachusetts, and Texas—accounted for approximately one-half of the entire national effort. The top 10 states—adding, in descending order, Pennsylvania, Illinois, Washington, and Maryland—accounted for approximately two-thirds of the national effort.

- ♦ **The United States spent $37.9 billion on the performance of basic research in 1998, $51.2 billion on applied research, and $138.1 billion on development, by current estimates.** These totals are the result of continuous increases over several years. They reflect a 4.7 percent annual increase, in real terms, for basic research; 3.9 percent for applied research; and 3.4 percent for development since 1980. As a share of all 1998 R&D performance expenditures, basic research represented 16.7 percent, applied research 22.5 percent, and development 60.8 percent. These shares have not changed very much over time.

- ♦ **R&D in the broad area of the life sciences is characterized by strong and fairly continuous real growth.** Federal obligations for research in the life sciences rose from $8 billion in 1985 (in constant 1992 dollars) to $11 billion in 1996. Company-funded R&D in drugs and medicines grew dramatically in real terms, from $4 billion in 1985 to $10 billion in 1997. Likewise, academic R&D (not Federally funded) in the life sciences and bioengineering/biomedical engineering grew continuously, from $3 billion in 1985 (in constant 1992 dollars) to $5 billion in 1996.

- ♦ **Growth in collaborative research is an important trend in R&D activities as a means of synergizing R&D investments.** By the end of 1998, 741 research joint ventures (RJVs) associated with NCRA and the National Cooperative Research and Production Act had been registered. By 1998, however, the number of new RJV filings had fallen sharply to 31 per year, after having reached a peak of 115 in 1996.

- ♦ **Cooperative research and development agreements (CRADAs) between Federal agencies and other sectors grew in number geometrically, from 34 in 1987 to 3,688 in 1996 (averaging 68 percent growth per year).** Between 1996 and 1997, however, the number of active CRADAs declined to 3,239.

## International Comparisons of National R&D Trends

- ♦ **The United States accounts for roughly 43 percent of the industrial world's R&D expenditure total.** U.S. R&D investments continue to outdistance, by more than 2 to 1, R&D investments made by Japan, the second largest performer. Not only did the United States spend more money on R&D activities in 1997 than did any other country, it also spent as much by itself as the other "group of seven" (G-7) countries—Canada, France, Germany, Italy, Japan, and the United Kingdom—combined. In terms of nondefense R&D spending, however, combined expenditures in those six countries exceeded nondefense R&D spending in the United States by 17 percent in 1996.

- ♦ **Relative to shares reported in other G-7 countries, U.S basic research spending (17 percent of its R&D total) is less than the shares reported for Germany, France, and Italy (each at 21–22 percent ) but higher than the basic research share in Japan (12 percent of its R&D total).** Basic research accounts for 18 percent of Russia's R&D total.

- ♦ **There was a worldwide slowing in R&D spending in large and small countries in the early 1990s.** In fact, inflation-adjusted R&D spending fell for three consecutive years (1992, 1993, and 1994) in the United States, Japan, Germany, and Italy. R&D spending has since recovered in these countries but has remained stagnant in France and the United Kingdom. Most of the recent R&D growth results from rebounding industrial nondefense spending.

- ♦ **The most notable trend among G-7 and other Organisation for Economic Co-operation and Development (OECD) countries has been the relative decline in government R&D funding.** In 1997, roughly one-third of all OECD R&D funds derived from government sources—down considerably from the 45 percent share reported 16 years earlier. Much of this change reflects a decline in industrial reliance on government funds for R&D performance. In 1981, government provided 23 percent of the funds used by industry in the conduct of R&D within OECD countries. By 1997, government's share of the industry R&D total had fallen by more than one-half, to 10 percent of the total.

- ♦ **Even with the recovery in R&D spending in many G-7 countries, their R&D/GDP ratios generally are no higher now than they were at the start of the 1990s.** The U.S. R&D/GDP ratio inched back up to 2.7 percent in 1998 from its 16-year low of 2.4 percent in 1994. The United States ranked sixth among OECD countries in terms of reported R&D/GDP ratios for 1995–97. Sweden leads all countries with a R&D/GDP ratio of 3.9 percent, followed by Japan and South Korea (2.9 percent), Finland (2.8 percent), and Switzerland (2.7 percent).

- ♦ **R&D spending in the Russian Federation remains considerably below levels in place prior to the introduction of a market economy.** R&D downsizing and restructuring of obsolete, state-owned (generally military-oriented) enterprises were undertaken to establish viable commercial and scientific R&D infrastructures. In 1997, inflation-adjusted R&D spending was 74 percent below the level reported for 1990, and the number of scientists and engineers employed in research was less than half the number estimated to be employed in 1990.

- ♦ **Worldwide changes in the R&D landscape are presenting governments with a variety of new challenges and**

**opportunities.** Defense R&D has been substantially reduced not only in the United States but also in the United Kingdom and France, where the national defense share of the government R&D total declined from 44 percent to 38 percent and from 40 percent to 28 percent, respectively, during the 1990–97 period.

- ♦ **Among nondefense functions, U.S. government R&D spending for health is far greater than for any other activity.** Health accounts for about 19 percent of government R&D, making it second only to defense R&D activities. In the United Kingdom, 15 percent of the government's R&D support is health related. Several additional nondefense functions are emphasized to different degrees among other G-7 countries. Relatively large shares of government R&D support are devoted to energy in Japan; to space in France and the United States; and to industrial development in Canada, Germany, and Italy.

- ♦ **Many countries have put fiscal incentives into place to increase the overall level of R&D spending and to stimulate industrial innovation.** Almost all industrialized countries (including the United States) allow industry R&D expenditures to be 100 percent expensed (written off as costs in expense statements) in the year they are incurred, and about half of these countries (including the United States) provide some type of additional R&D tax credit or incentive. In fiscal year 1998, U.S. industry received an estimated $3.2 billion through tax credits on incremental research and experimentation expenditures. About 15 states in the United States offer additional R&D tax credits. Most countries (including the United States) provide preferential R&D programs for small businesses.

- ♦ **International partnerships have become a pillar in the global R&D landscape.** In many countries, the rapid rise in international cooperation has spawned activities that now account for more than 10 percent of government R&D expenditures. According to a 1999 study, seven agencies of the U.S. government participated in 575 international science and technology agreements in FY 1997 with 57 countries, 8 international organizations, and 10 groups of organizations or countries.

- ♦ **Industrial firms increasingly have used global research partnerships to strengthen core competencies and expand into technology fields critical for maintaining market share.** Since 1990, companies worldwide have entered into more than 5,100 known multifirm R&D alliances involving strategic high-technology activities. About one-third of these alliances were between U.S. firms and European or Japanese firms. Alliances were created most often to develop and share information technologies.

- ♦ **Worldwide, an increasing share of industrial R&D performance is financed by foreign (generally industry) sources.** U.S. companies make substantial R&D investments overseas ($13.1 billion in 1997). From 1985 to 1996, U.S. firms' investment in overseas R&D increased almost three times faster than company-funded R&D performed domestically (9.7 percent versus 3.4 percent average annual constant-dollar growth). Equivalent to about 6 percent of industry's total (domestic plus overseas) R&D funding in 1985, overseas R&D represented 10.4 percent of U.S. industry's R&D funding in 1996. In 1997, strong growth in companies' domestic financing for research (up 10 percent) coupled with a 7 percent decline in industry's overseas R&D spending reduced the overseas share to 8.9 percent of companies' R&D total.

- ♦ **More than two-thirds of U.S.-funded R&D abroad was performed in Europe—primarily in Germany, the United Kingdom, and France.** The current European share of U.S. industry's offshore R&D activity, however, is less than the 75 percent share reported for 1982. Overall, U.S. R&D investments abroad have generally shifted from the larger European countries and Canada toward Japan, several of the smaller European countries (notably Sweden and the Netherlands), Australia, and Brazil. Pharmaceutical companies accounted for the largest industry share (18 percent of U.S. 1997 overseas R&D), which was equivalent to 21 percent of their domestically financed R&D. Much of this pharmaceutical R&D took place in the United Kingdom.

- ♦ **U.S. firms are known to have established at least 186 R&D facilities in other countries by 1997.** Japan leads all countries as the site of overseas U.S. R&D facilities (43), followed by the United Kingdom, Canada, France, and Germany. Most U.S.-owned foreign facilities support the automotive (32 facilities), drugs and biotechnology (28), computers (25), and chemicals and rubber (23) industries.

- ♦ **Substantial R&D investments are made by foreign firms in the United States.** From 1987 to 1996, inflation-adjusted R&D growth from majority-owned U.S. affiliates of foreign firms averaged 10.9 percent per year. This growth contrasts favorably with the 3.9 percent average annual rate of increase in U.S. firms' domestic R&D funding. R&D expenditures in the United States by foreign companies are now roughly equivalent to U.S. companies' R&D investment abroad. Affiliates of firms headquartered in Germany, Switzerland, the United Kingdom, France, Japan, and Canada collectively account for 81 percent of this foreign funding.

- ♦ **Foreign-funded R&D in the United States in 1996 was concentrated in drugs and medicines (mostly from Swiss, German, and British firms), industrial chemicals (funded predominantly by German and Dutch firms), and electrical equipment (one-third of which came from French affiliates).** More than 700 R&D facilities run by 375 foreign-owned companies from 24 different countries are located in the United States.

# Introduction

## Chapter Overview

The U.S. economy approaches the end of the 20th century with unprecedented real growth, miniscule inflation, low unemployment, and strong consumer and investor confidence. Economists have dubbed it the "Cinderella economy." The reasons for this success are many and varied. However, it can be argued that technological change has been behind the economic boom of the late 1990s.

Technological change has three general effects on the economy. First, it reduces the costs of producing goods and providing services. That is, technological change allows for the consumption of greater amounts of goods and services, without the use of greater amounts of human labor, physical capital, or natural resources. Second, technological change is responsible for the creation of new and improved goods and services. Although the relative value of any new product is subjectively determined by each individual, the spending patterns of consumers overall often reveal the preferability of these new products over their predecessors. Ironically, the third factor—what technological change has not yet done, but is expected to do—may have made the greatest contribution to the recent economic boom. Technological change is expected to continue to transform many aspects of economic production, distribution, and consumption. Such changes include, for example, further development of Internet commerce (e.g., banking and retail operations), additional advances in biotechnology (e.g., "designer" drugs), greater automation in production (e.g., advanced robotic systems), new forms of household entertainment (e.g., digital video disc entertainment systems), and new ways of conducting scientific research itself (e.g., the creation of virtual laboratories). Investors and public planners have continued to devote new resources to preparing for these changes, thereby stimulating economic investment and expansion. Thus, much of the current investment-led economic growth is only a prelude to future advances. In this sense, our present is being influenced largely by our future—a future that will owe much of its character to technological change.

Of course, innovation—and the technological change that results from it—does not just happen. It has to be paid for—through expenditures on research and development (R&D). How R&D funds are spent helps determine how scientific knowledge will accumulate and how technological change will be manifested. Thus, R&D decisionmaking—how much different organizations spend and on what areas of science or engineering—is critical to the future of the U.S. economy and national well-being. This factor explains why the United States and many other nations collect extensive R&D expenditures data and disseminate the information worldwide for study by analysts in a wide variety of fields.

In addition to indicating the directions of technological change, R&D expenditure data also measure the level of economic purchasing power that has been devoted to R&D projects as opposed to other economic activities. Industrial (private sector) funding of R&D, for example—which represents most of R&D expenditure in the United States—may be interpreted as an economic metric of how important R&D is to U.S. companies, which could have easily devoted those same funds to any number of other business activities. Likewise, government support for R&D reflects government and society's commitment to scientific and engineering advancement, which is an objective that must compete for dollars against other functions served by discretionary government spending. The same basic notion holds for other sectors that fund R&D, such as colleges and universities and other nonprofit organizations.

Total R&D expenditures therefore reveal the *perceived* economic importance of R&D *relative* to all other economic activities. Because institutions invest in R&D without knowing the final outcome (if they did, it would not be R&D), the amount they devote is based on their perception, rather than their absolute knowledge, of R&D's value. Such information about R&D's perceived relative value is also extremely useful for economic decisionmaking. For example, increased R&D in a particular field of study may reflect an increase in demand for scientists and engineers to study and work in that field. An increase in R&D in a particular industrial sector could be among the first signs that the sector is about to expand with new lines of products or services. Of course, R&D data alone are not enough to accurately analyze the future growth of a field of study or an industrial sector, but they may well be an important input into such analysis. This chapter therefore presents information that will provide a broad understanding of the nature of R&D expenditures and the implications of these data for science and technology policy.

## Chapter Organization

This chapter has two major parts, both of which examine trends in R&D expenditures. The first part looks into R&D performed in the U.S. alone; the second compares R&D trends across nations. The first part contains sections on economic measures of R&D; trends in financial support for R&D; trends in R&D performance; industrial R&D performance; R&D performance by geographic location, character of work, and field of science; and intersector and intrasector R&D partnerships and alliances. The second part contains sections on total and nondefense R&D spending; ratios of R&D to gross domestic product (GDP) among different nations; international R&D funding by performer and source; the character of R&D efforts (or R&D efforts separated into basic research, applied research, and development components); international comparisons of government R&D priorities; comparisons of government R&D tax policies; the growth in public- and private-sector international R&D agreements and alliances; the United States' international R&D investment balance; and patterns in overseas R&D and foreign R&D performed in the United States, in terms of both expenditures and facility placement.